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Management of natural gas resources and search for alternative renewable energy resources: A case study of Pakistan

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ABSTRACT

Energy usage in Pakistan has increased rapidly in past few years due to increase in economic growth. Inadequate and inconsistent supply of energy has created pressure on the industrial and commercial sectors of Pakistan and has also affected environment. Demand has already exceeded supply and load shedding has become common phenomenon. Due to excessive consumption of energy resources it would become difficult to meet future energy demands. This necessitates proper management of existing and exploration of new energy resources. Energy resource management is highly dependent on the supply and demand pattern. This paper highlights the future demands, production and supply of energy produced from natural gas based on economic and environmental constraints in Pakistan with special emphasis on management of natural gas. An attempt has been made by proposing a suitable course of action to meet the rising gas demand. A mechanism has been proposed to evaluate Pakistan's future gas demand through quantitative analysis of base, worst and best/chosen option. CO_2 emission for all cases has also been evaluated. The potential, constraints and possible solutions to develop alternative renewable energy resources in the country have also been discussed. This work will be fruitful for the decision makers responsible for energy planning of the country. This work is not only helpful for Pakistan but is equally important to other developing countries to manage their energy resources.

Contents

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1. Introduction

The supply of natural gas in the country is becoming inconsistent day by day while demand is increasing. Increase in demand is because natural gas is environmental friendly and its price is less as compared to other energy resources. Due to this inconsistency each sector of the society is being affected including domestic, commercial and industrial sectors. Unfortunately no serious attempt is being made to install new capacity for energy generation. The need of the time is to properly manage the reserves of natural gas inside the country and to look for alternative options outside the country. Natural gas is Pakistan's biggest energy resource contributing to 50% of the total energy mix. This share increased to 52% in 2005. The total proven natural gas reserves in Pakistan are 28 trillion cubic feet. Reserve to Production (R/P) ratio based on the production of 2005 was to fulfill requirements of 23 years [1]. But if the pattern for demand/supply remains same the R/P ratio would reduce remarkably and search for new options of natural gas would become necessary. In Pakistan gas consumption increased from 0.786 TCF to 1.223 TCF within 5 years (2001–2007) [2]. This increase was due to 59% growth of all sectors consuming natural gas as their primary energy source.

Sector wise gas consumption, projected gas supply in the country without imports, projected gas demand (constrained) and projected gas-supply demand balance (without imports) have been shown in Figs. 1–5.

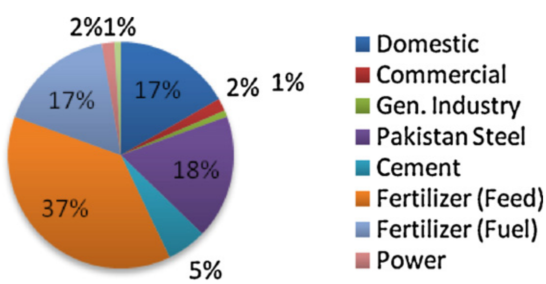

Fig. 1. Sector wise gas consumption (2001–2002).

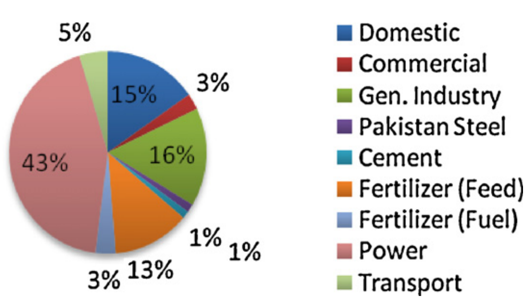

Fig. 2. Sector wise gas consumption (2006–2007).

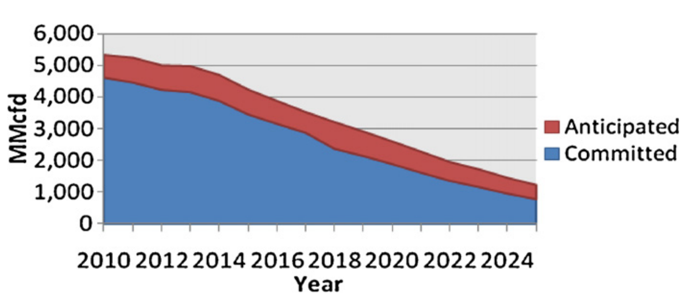

Fig. 3. Projected gas supply in MMcfd (without imports).

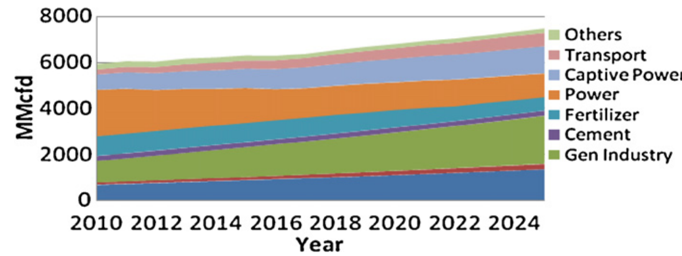

Fig. 4. Projected gas demand (constrained).

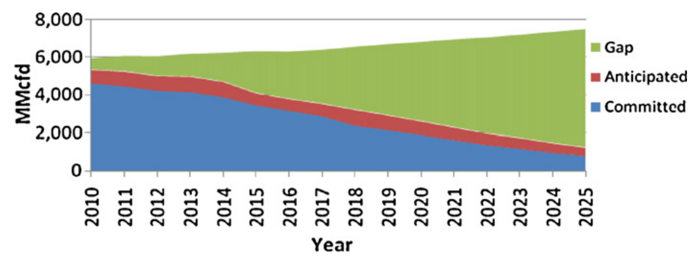

Fig. 5. Projected gas-supply demand balance (without imports).

It has been shown clearly that the gap between demand and supply would increase at a much higher rate in future. The major reason for rapid increase of natural gas demand in Pakistan is the surge extension of energy intensive production. The search for new options to get natural gas is necessary due to its extensive use as energy resource in domestic, commercial, fertilizer, cement, transport (CNG) and power sectors. Fig. 4 shows that natural gas consumption by power sector would increase from 2000 MMcfd in year 2010 to 3500 MMcfd in year 2025. This trend is similar for other sectors consuming natural gas.

Natural gas is a clean source of energy. Upon combustion it produces carbon dioxide and water vapors, the same we exhale during breathing process. It is the cleanest of all fossil fuels. The only green house gas emitted by burning natural gas is carbon dioxide which could create environmental problems. Upon combustion other fuels produce more complex molecules containing high carbon, nitrogen and sulfur contents (Fig. 6).

This chart is still current as of 2010. The environmental friendly nature of natural gas, as compared to other fossil fuels, necessitates the search for its exploration within country and import from other countries. Thus increasing domestic production, embarking on transnational pipelines and LNG imports is the main strategy which can be used to bridge the supply–demand gap. Prioritization of sectors for using natural gas as energy resource is also important. The government of Pakistan is working on various policies for efficient utilization and conservation of energy. The Ministry of Petroleum and Natural gas made various policies for allocation and management of natural gas. The policies published emphasize on

Fossil Fuel Emission Levels
- Pounds per Billion Btu of Energy Input

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide	117,000	164,000	208,000
Carbon Monoxide	40	33	208
Nitrogen Oxides	92	448	457
Sulfur Dioxide	1	1,122	2,591
Particulates	7	84	2,744
Mercury	0.000	0.007	0.016

Source: EIA - Natural Gas Issues and Trends 1998

Fig. 6. Fossil fuel emission levels for natural gas, oil and coal.

Table 1
Technologies contributing to energy efficiency and GHG (green house gases) emission reductions in short and middle terms.

Sector	Technologies	Energy saving	Environmental benefits
Iron and steel	Smelting reduction processes/oxy-fuel combustion in reheat furnace	High	Significant
Petroleum refining	Fouling minimization	High	N/A
Pulp and paper	Black liquor gasification/condebelt drying/heat recovery/high consistency forming	High	Somewhat
Fertilizer	Sensors and controls	High	N/A
Food processing	Electron beam sterilization/membrane technology	High	Somewhat
Chemicals	Heat recovery technologies/plastic recovery	Medium	N/A
Aluminium	Inert anodes/wetted cathodes, efficient cell retrofit designs	High	Significant
Cross-cutting	Advanced lighting technologies/advanced lighting design/compressed air system management/motor system optimization/pump efficiency improvement/membrane technology wastewater/sensors and controls	High	Somewhat

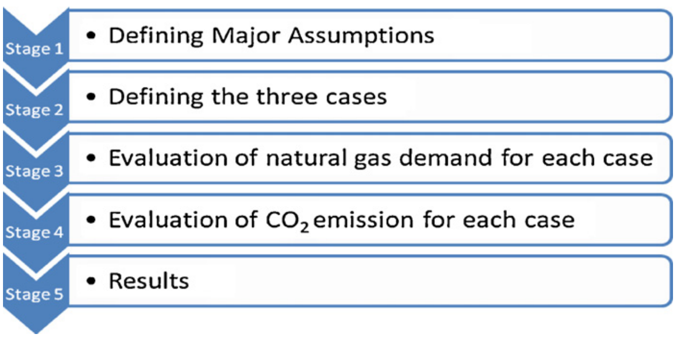

Fig. 7. Proposed model.

establishing Natural gas Allocation and Management Plan to promote efficacious utilization of precious depleting natural resource. This plan includes prioritization of users, criteria for gas allocation, load management policy, augmenting gas supply and network extension.

2. Energy and emission scenarios for Pakistan

2.1. Methodology

A model, Fig. 7, is developed to study the interaction between energy and environment in Pakistan. Increased concern around the environmental friendly energy usage and sustainable development describes the importance of such model. This model uses natural gas demand projection, CO_2 emission evaluation and energy efficiency technology selection to evaluate three cases. The demand is calculated based on domestic, cement, captive power, fertilizer, transportation, general industry, power, commercial and other sectors. Existing as well as future advanced technologies were considered for both demand and supply side. Most up to date information was collected from various sources to apply this model.

2.2. Major assumptions

The major assumptions used in the study are given in the following tables.

Population	Year			
	2000	2010	2020	2030
Total	138	170	204	236
Urban	42	51	63	71
Rural	96	119	141	165

Population assumption, million.
Note: Assumption by author, based on review of relevant studies.

Annual GDP growth rate	Year		
	2000–2010	2010–2020	2020–2030
	6.16	6.76	6.33

Real GDP growth in Pakistan [2].

2.3. Cases

Three cases have been established, defined as follows, to analyze future natural gas demand and CO_2 emission in Pakistan.

2.3.1. Base case

This case gives a basic pattern of natural gas demand based on future economic activities. Through better international trading, Pakistan's economy will be part of global economy. Therefore Pakistan could rely on international markets and energy resource imports to meet part of its energy supply needs. So the pressure on domestic natural gas resources is relieved to some extent.

2.3.2. Worst case

This case would indicate a high demand for natural gas in future. The major reason is Pakistan's economic growth. Based on World Bank studies the economic growth of Pakistan is increasing by 6.5% every year.

Table 2
Policy options for best case.

Policy options	Explanation
Load management policy/prioritization of consumer	In peak season (winter) domestic consumers get continuous supply, fertilizer industry gets full supply, supply to industries having 9 months contracts is disconnected, power plants get gas supply after fulfillment of domestic and commercial needs, cement industry gets supply on 'as and when available' basis
Gas allocation criteria	Domestic consumers will get allocation according to yearly target determined by federal government, supply to commercial consumers is encouraged, allocation to fertilizer sector will be determined by federal government keeping in view the domestic and commercial needs of the country and the supply available, for the industrial sector gas supply for process gas will be based on 12 months and for other purpose gas supply will be on best effort basis, in power sector allocation to only new dual fired power technology plants, with proper safeguards to protect interest of supplier/federal government against non-availability of gas supply for unforeseen events, will be made.
Gas supply enhancement policy	Increase gas supply from indigenous sources, encouraging import options
Technology promotion policy	New technology introduced for end use technology efficiency
Transport efficiency improvement	Promoting use of high fuel efficiency vehicles
Search for renewable energy development	Promoting use of renewable energy options such as wind power and biomass power generation
Policy implementation	Follow up by the federal government to ensure implementation of allocation and management policy

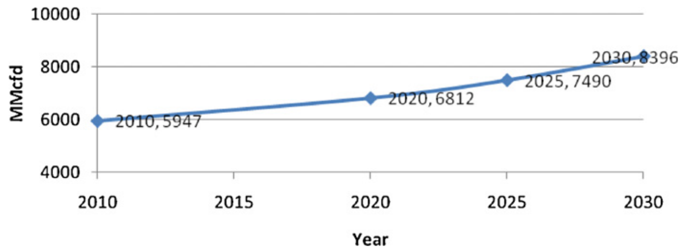

Fig. 8. Natural gas demand for base case in Pakistan.

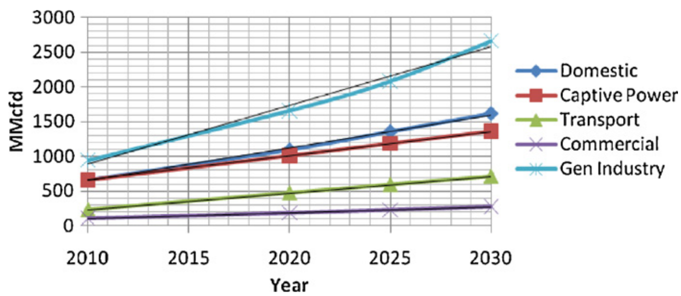

Fig. 9. Natural gas demand by sector for base case.

2.3.3. Best case

This case gives a low demand scenario through energy efficiency technology and energy & emission control policies shown in Tables 1 and 2 respectively. The best case is based on natural gas supply and environmental constraints. Technologies which could contribute to energy savings in various industries are shown in Table 1. Environmental benefits of each technology are also identified. However, much effort is required for the planning, research, development and implementation of such technologies.

Following table shows the policy options designed for best case. These policy options include the existing policies, developed by Ministry of Petroleum and Natural gas, without strict implementation, and new policies defined by the author.

2.4. Results

Natural gas demand evaluated for base, worst and best cases has been shown in Table 3. The total gas demand for base, worst and best cases in Year 2030 is evaluated to be 8396, 18 322 and 8033 MMcfd or 3 064 540, 6 687 530 and 2 932 045 MMcf per year respectively.

Natural gas demand for each case is evaluated. For base case the energy demand will go up to 6812 MMcfd till 2020 and 7490 till 2030. Natural gas demand for worst case in 2030 is 18 322 MMcfd, which is almost three times higher than base case. For best case natural gas demand in 2030 is 8033 MMcfd. Demand of natural gas for base, worst and best cases has been shown in Figs. 8–13. Comparison of three cases has been shown in Fig. 14.

CO_2 emission calculated for base, best and worst cases, based on the natural gas demand for each case, has been shown in Fig. 15.

Comparison of three cases clearly shows that adoption of the best case, based on policy option and energy efficiency technology,

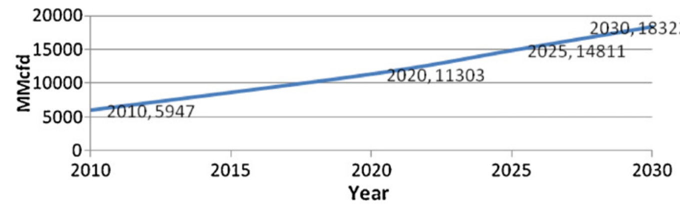

Fig. 10. Natural gas demand for worst case.

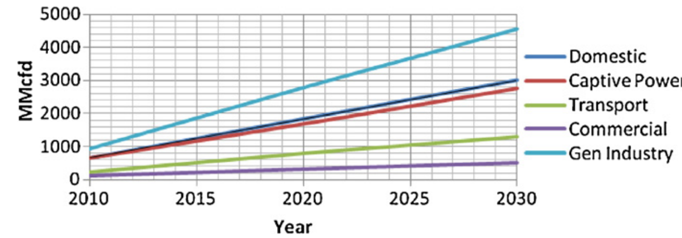

Fig. 11. Natural gas demand by sector for worst case.

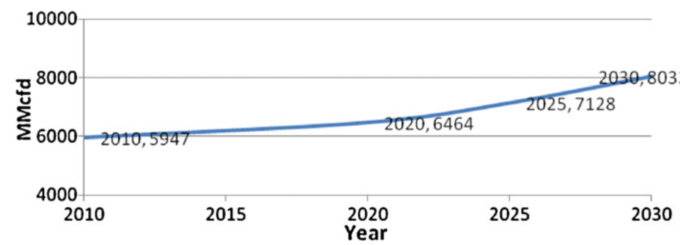

Fig. 12. Natural gas demand for best case.

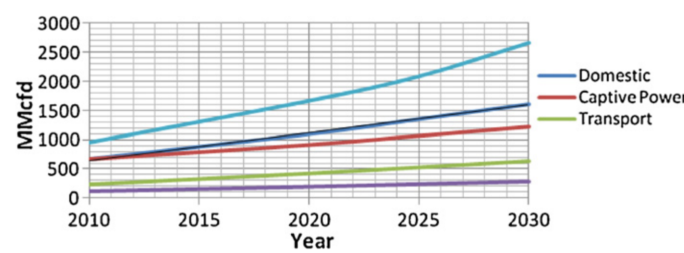

Fig. 13. Natural gas demand by sector for best case.

Table 3
Natural gas usage by sector.

Product	Unit	2010	Base case			Worst case			Best case		
			2020	2025	2030	2020	2025	2030	2020	2025	2030
Domestic	MMcfd	661	1097	1356	1615	1839	2421	3003	1097	1356	1615
Cement	MMcfd	214	214	214	214	214	214	214	214	214	214
Captive power	MMcfd	660	1010	1185	1360	1692	2227	2763	909	1066	1224
Commercial	MMcfd	108	187	232	277	313	412	511	187	232	277
Fertilizer	MMcfd	869	780	619	530	1307	1720	2134	702	557	477
Transport (CNG)	MMcfd	233	475	594	713	796	1048	1300	427	534	642
Gen industry	MMcfd	946	1662	2084	2662	2785	3666	4548	1662	2084	2662
Power	MMcfd	2019	1211	1025	839	2029	2671	3313	1090	922	755
Others	MMcfd	237	196	181	186	328	432	536	176	163	167
Total	MMcfd	5947	6812	7490	8396	11303	14811	18322	6464	7128	8033

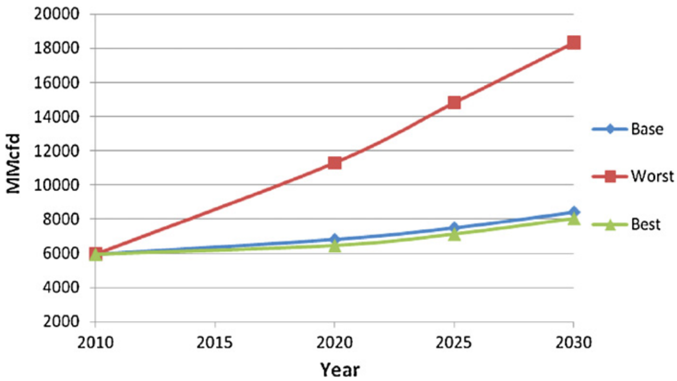

Fig. 14. Comparison of natural gas demand among all cases.

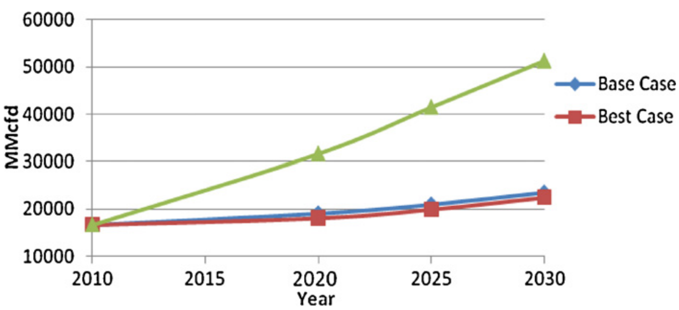

Fig. 15. CO_2 emission in Pakistan by using natural gas.

not only decreases the demand of natural gas but also reduces the CO_2 emission into the environment.

3. Alternative renewable energy resources available in Pakistan

The possible or potential renewable energy resources available in Pakistan include hydro, solar, wind, biomass and geothermal energy.

3.1. Hydropower

Hydropower refers to the energy produced from water (rainfall, etc.). Hydropower plants are located in the regions of rainfalls. Pakistan's potential for hydro power is about 45 000 MW, whereas currently only 6500 MW capacity plants have been installed. 30 000 MW potential is identified on the main rivers. Additional amount of hydel potential is also available outside the main river valleys in the northern mountaneous regions including AJ & K which has not been evaluated so far. In the long term planning it is proposed to increase hydro power from 6500 MW (11% in primary energy mix) to about 32 100 MW (20% in primary energy mix) by 2030. This means 30% share in Power Generation. This will require 8000 MW small/medium hydro units on rivers/canals, run of the river plants and four large hydro multipurpose reservoirs/dams with capacity of about 17 600 MW up to 2030. The four large Hydro Dams are: (i) Kalabagh – 3800 MW, (ii) Bhasha – 4600 MW, (iii) Bunji – 5400 MW, (iv) Dasu – 3800 MW [3].

The annual rainfall of Pakistan has been shown in Figs. 16 and 17.

The constraints for planning, development and implementation of large scale hydel projects include long construction period, high capital cost and dependence on seasonal variation in river flows. The possible solution could be development of medium scale projects requiring low gestation period and low capital cost, hydel stations having characteristics to generate more power during April to June and development of small hydel projects for isolated areas.

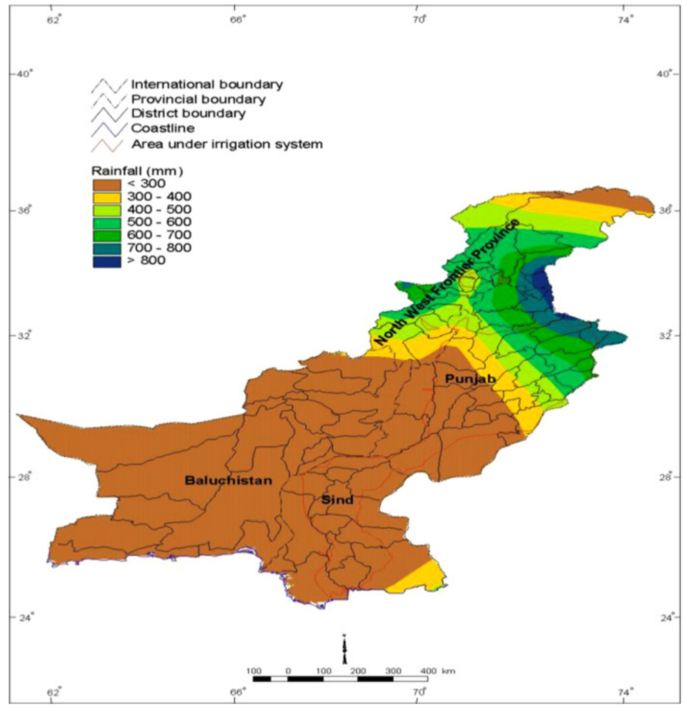

Fig. 16. Annual average rainfall pattern in Pakistan.
Source: International Water Management Institute.

Location map of current and future hydropower projects of Pakistan has been shown in Fig. 18.

3.2. Solar energy

Pakistan has an average annual temperature of 26–28 °C. Thus that Pakistan has potential for solar energy. Annual mean temperature of Pakistan has been shown in Fig. 19. The sunniest parts of the country include South Western province of Balochistan and North Eastern part of Sindh. In these areas sun shines between seven and eight hours daily. Although there is a huge potential for solar energy but its usage for electricity generation or heating is still in initial stages. Photovoltaic (PV) systems of 100–500 W/unit electricity generation capacity are being used in some of the rural areas of the country which provide electricity to villages. 40 000 villages have no access to electricity and with the present pace of energy sector development it would take 50 years to electrify these villages [6]. PV systems have low efficiency factor but they have advantage of having no moving parts. PV systems find applications in individual home rooftop system, solar dryers, solar torch/portable lights, community street lights, PV charger, solar desalination units, community water pumping and solar water heaters. These systems

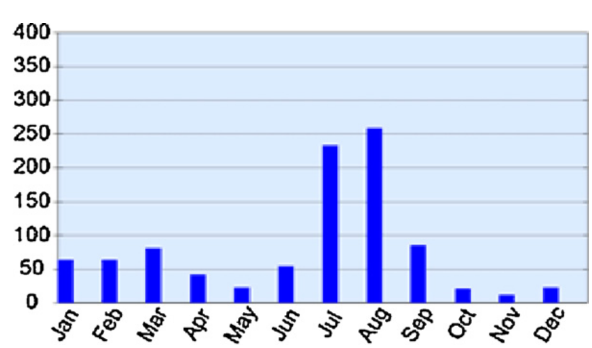

Fig. 17. Average monthly rainfall in Pakistan [4].

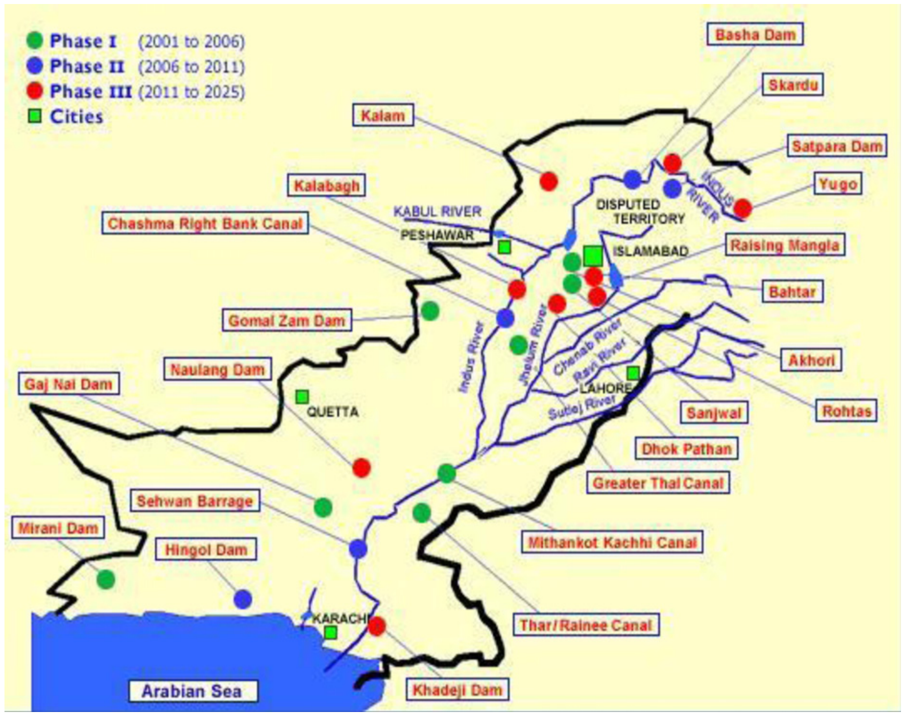

Fig. 18. Location map of hydropower projects of Pakistan [5].

Table 4
CO_2 emission for base, worst and best cases.

CO_2 Emission	2010	Base case			Worst case			Best case		
		2020	2025	2030	2020	2025	2030	2020	2025	2030
MMcfd	16 652	19 074	20 972	23 509	31 648	41 471	51 302	18 100	19 959	22 492

have been designed and are in limited use but their contribution in energy needs of the country is negligible. PCRET and AEDB are government organizations working on solar energy development of the country. PCRET has 80 kW of total PV power generation, AEDB has 200 kW of total PV power generation and private sector PV installations contribute to 500 kW [7]. In private sector more than 20 manufacturers are active in solar energy business. So, Pakistan has growing solar energy sector but a lot more is required to develop this sector which will not only help meet the energy needs of the country but will also create job growth in the country (Table 4).

Solar radiation map of Pakistan has been shown in Fig. 20. Tables 5 and 6 show GIS data at 10 km and 40 km resolution respectively.

3.3. Wind energy

Pakistan has huge potential for wind energy but it is a missed opportunity till now. In Pakistan 346 000 MW potential has been identified by the wind map developed by National Renewable Energy Laboratory (NREL), USA in collaboration with USAID.

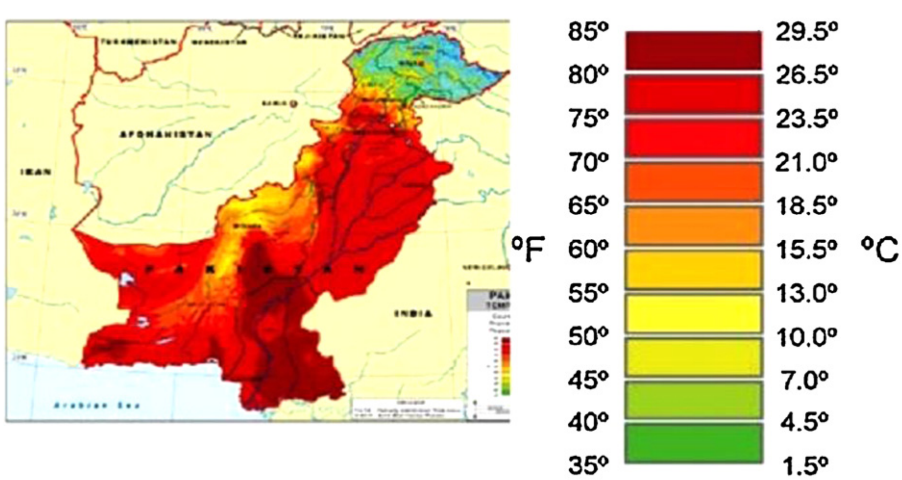

Fig. 19. Annual mean temperature of Pakistan [8].

Table 5
GIS data at 10 km resolution (irradiance is in watt hours/M^2/day) [10].

Gridcode	66052405	66.100	24.000													
		^ Longitude	^ Latitude													
Month->				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Direct	66052405	66.05	24.05	4929	5238	5254	4986	4238	2402	1762	1846	3374	4957	4766	4776	4036
Global	66052405	66.05	24.05	4187	5134	6162	6511	6790	5748	4852	4846	5462	5364	4468	3907	5284
Latitude Tilt	66052405	66.05	24.05	5557	6263	6844	6967	5927	5368	4558	4786	5815	6061	5701	5304	5752

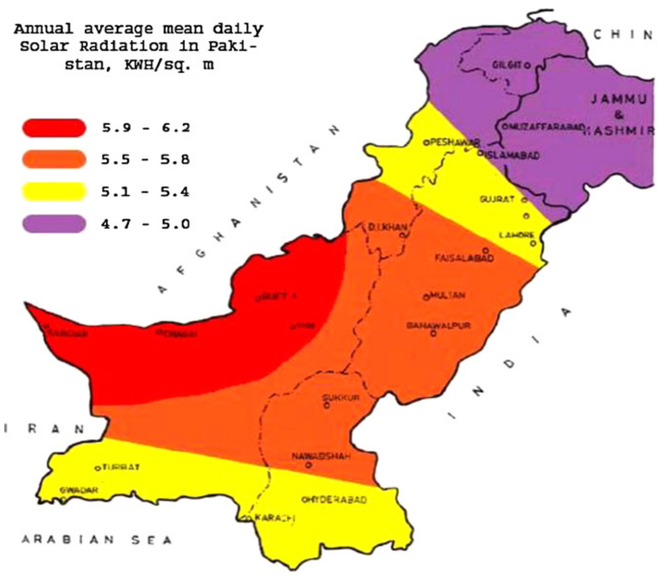

Fig. 20. Solar radiation map of Pakistan [9].

Gharo-Keti Bandar has a potential of approximately 50 000 MW [11]. Gharo-Keti Bandar wind corridor, 60 km along the coastline of Sindh Province and more than 170 km deep towards the land, alone has a potential of approximately 50 000 MW. Fig. 21 shows that wind speed of 5–7 m/s prevails in coastal regions of Sindh and Balochistan provinces and in a number of North West frontier valleys. Gharo-Keti Bandar in Thatta district of the Sindh Province and Lasbella District of Balochistan Province are the areas where wind at a sustainable speed is available. But unfortunately no serious attempts were made in past for planning and development of wind power projects. Only some micro plants of 300–500 W capacity were developed for generating electricity. Almost 100 wind power systems were used for pumping water in Balochistan and Sindh provinces in the last 4 years. PCRET installed 155 units of total generating capacity of 143 kW with wind turbines of 0.5–10 kW capacity/unit while electrifying 1600 houses. More than 400 wind electrification applications are in progress [12]. Wind energy development plan for Pakistan has been shown in Fig. 22.

3.3.1. Advantages

Wind Power Generation has many advantages:

- Green energy source with no pollution.
- Effective and low gestation period.
- Equipment erection and commissioning is simple and requires few months.
- No extra fuel is required for power generation so no price risk involved.
- Power supply to remote areas of the society is possible.
- Job creation.

Since there is a huge potential and advantages of wind power so government along with private sector should work together for the development and implementation of wind power technology in the country. Wind electric potential of Pakistan has been shown in Fig. 23.

Fig. 21 shows Wind Resource Assessment and Mapping for Pakistan, developed by NREL (National Renewable Energy Laboratory) and USAID. Computerized mapping approach using Geographical Information System (GIS) software (ArcInfo® and ArcView®) has been used to develop this map [13].

3.4. Biomass

Biomass includes solid biomass, biogas, liquid biofuels and municipal waste. It is considered as a clean and reliable source of renewable energy. The most common successful sources of biomass energy in Pakistan are animal dung in livestock, sugarcane bagasse in agriculture and pulp and paper residues in forestry. Location Map of agriculture and land use of Pakistan has been shown in Fig. 24.

With the growing population of Pakistan, waste is increasing day by day and is becoming a threat to the environment. In the past no

Table 6
GIS data at 40 km resolution (irradiance is in watt hours/M^2/day) [10].

Cell Id	342108														
	Longitude	Latitude													
Month			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Direct	70.068	21.07	6160	6215	5442	5857	4833	1502	568	908	2757	5762	5457	5894	4279
Global	70.068	21.07	4665	5405	6120	6786	6721	5479	4275	4341	5146	5624	4798	4448	5317
Latitude Tilt	70.068	21.07	6034	6492	6653	6800	6335	5118	4032	4199	5302	6484	5979	5866	5774
Diffuse	70.068	21.07	1150	1459	2204	2344	2944	4224	3803	3605	3060	1794	1521	1208	2443

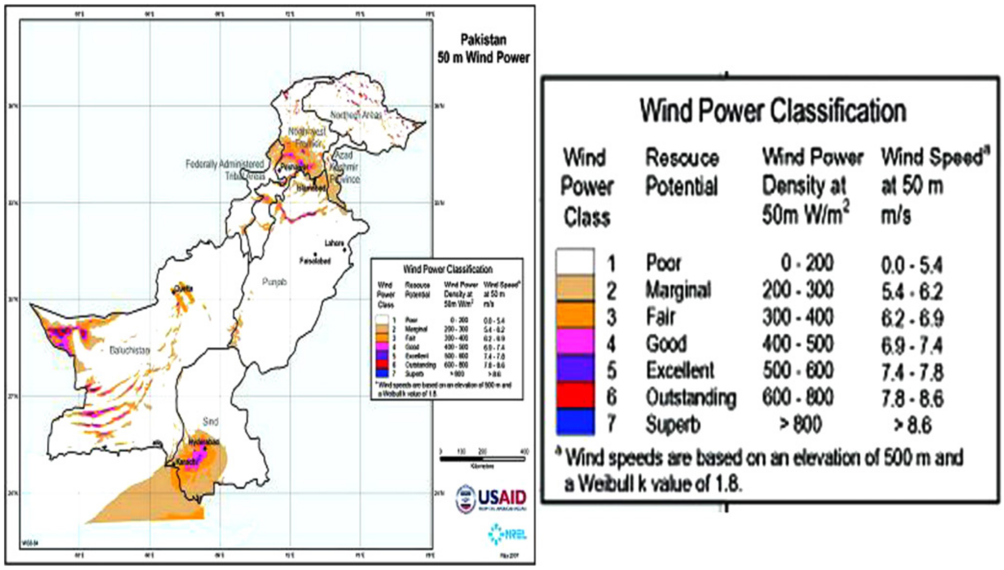

Fig. 21. Wind power map of Pakistan [13].

PAKISTAN - WIND ELECTRIC POTENTIAL

Good-to-Excellent Wind Resource at 50 m (Utility Scale)

Wind Resource Utility Scale	Wind Class	Wind Power W/m ^{2}	Wind Speed m/s	Land Area km^2	Percent Windy Land	Total Capacity Installed MW
Good	4	400 - 500	6.9 – 7.4	18,106	2.1	90,530
Excellent	5	500 - 600	7.4 – 7.8	5,218	0.6	26,090
Excellent	6	600 - 800	7.8 – 8.6	2,495	0.3	12,480
Excellent	7	> 800	> 8.6	543	0.1	2,720
Total				26,362	3.0	131,800

Assumptions
Installed capacity per km ^{2} = 5 MW
Total land area of Pakistan = 877,525 km^2
Only land area included in calculations

Fig. 22. Wind energy development plan for Pakistan [9].

attempt was made to utilize waste for power generation. Waste-to-energy technologies will not only help improve the environment but will also contribute to energy needs of the country.

According to PCRET based on the current livestock census, there is a biogas generation potential of 19.125 million m^3/day which could meet the cooking needs of about 50 million people. Out of total population of 170 million of the country, 68% reside in the rural areas. So from this source cooking/heating requirements of 44% rural masses can be meet. As a result, 21.00 million tons of bio-fertilizer per year will be produced, which is an essential requirement for sustaining the fertility of agricultural lands. PCRET initially installed 1600 biogas plants. After successful installation and encouraged response from public, PCRET initiated another project in 2007 to install 2500 biogas plants. 2000 plants have been already installed and 500 are in progress. Initially biogas plants were only used for domestic cooking/heating purposes. But prevailing conditions of energy crisis in the country increased fossil fuel prices, load shedding and increased electricity tariff increased its importance to be used on commercial scale. So bigger biogas plants (10 m^3, 15 m^3, 20 m^3 gas production capacity per day) have been designed and successfully installed in Sialkot, Narowal, Jhang and other places [12].

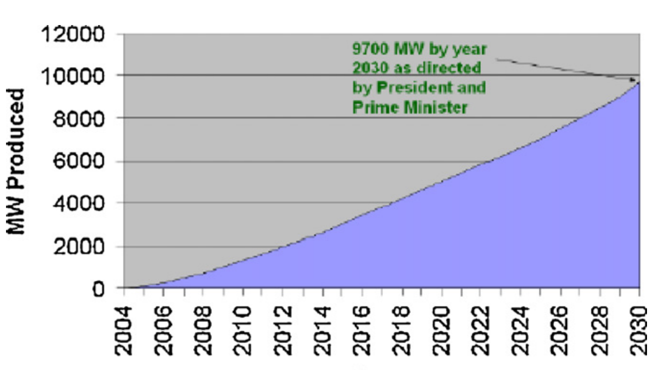

Fig. 23. Wind electric potential of Pakistan [13].

3.5. Geo thermal

Geo thermal power is another clean/green source of energy. It is also cost effective source of energy. No work has been done in Pakistan in the past to exploit Geo thermal energy. Pakistan is

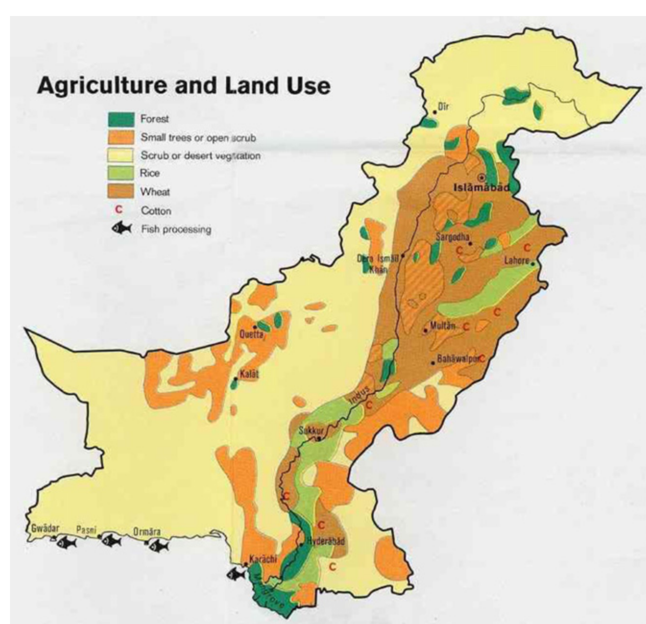

Fig. 24. Location map of agriculture and land use of Pakistan [14].

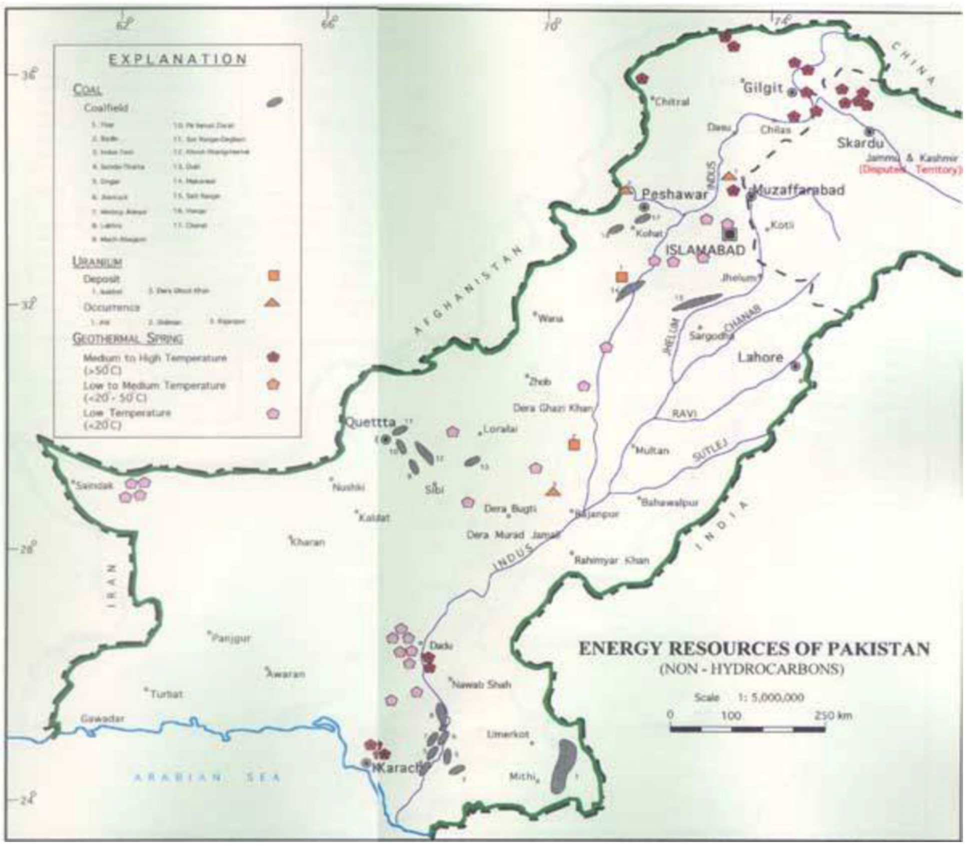

Fig. 25. Software generated map of geothermal spring, uranium and coal reserves of Pakistan [15].

rich in geothermal resources. Kashmir, NWFP and Balochistan are the potential locations of geothermal resources. A lot of work is required for research, development, planning and implementation of geo thermal power plants in Pakistan. Fig. 25 shows location map of geothermal spring, uranium and coal reserves of Pakistan.

4. Conclusion

Energy crisis is a global issue. Countries are looking for all possible solutions for energy management. The need of the time is to manage existing resources of energy and to explore new sources of both non-renewable and renewable resources. Pakistan is rich in natural gas resources but its management is poor. Energy planners should adopt policy option and energy efficiency technologies for future energy generation. Pakistan is also rich in renewable energy resources and has huge potential for these green resources. The development of renewable energy projects in Pakistan is in its initial stage. To cope up with energy crisis Pakistan should work on the planning, R&D and implementation of renewable energy sources.

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